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DOCUMENTATION OF DECISION-AIDING SOFTWARE: INTRODUCTORY GUIDE

DECISIONS AND DESIGNS INC.

Roy M. Gulick

February 1980

ADVANCED DECISION TECHNOLOGY PROGRAM

CYBERNETICS TECHNOLOGY OFFICE
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TECHNICAL REPORT 79-1-93

DOCUMENTATION OF DECISION-AIDING SOFTWARE:
INTRODUCTORY GUIDE

by

Roy M. Gulick

Sponsored by

Defense Advanced Research Projects Agency
ARPA Order 3469

February 1980

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The development of decision-aiding computer software addresses the need for practical and useful decision-aiding methodology for Defense decision makers and embodies the fundamental concepts of decision analysis. This manual briefly discusses the need for decision aids, identifies seven decision aids that were chosen for documentation, and describes the nature of the software documentation available to prospective users of the aids. The documentation has been written independently of computer and programming language and

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therefore can be applied to the development of software that implements an operational version of the aids on any host computer using any computer language.

ACKNOWLEDGMENTS

This guide introduces prospective users to seven packages of decision-aiding software and the twenty-one manuals that comprise the software documentation. The authors of the twenty-one manuals were tasked with documenting existing software that was, for the most part, designed and developed over a period of several years by other members of the professional staff of Decisions and Designs, Inc.

Credit for the original conception and design of the seven decision aids lies collectively with Dr. Cameron R. Peterson, Dr. Clinton W. Kelly, and Dr. Scott Barclay. Dr. L. Scott Randall managed the overall software development effort.

Mr. James J. Allen wrote the original software for the DECISION, EVAL, OPINT, INFER, and RAM aids. Dr. James O. Chinnis wrote the original software for the SCORING RULE aid and the HIER aid. Ms. Dorothy M. Amey completed the development of the OPINT and INFER aids and extended the generality of the HIER aid to the version described herein. Ms. Janice E. Ragland completed the development of the RAM aid.

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INTRODUCTORY GUIDE TO DECISION-AIDING SOFTWARE

1.0 INTRODUCTION

> *"The planning and conduct of war have acquired a precision, a swiftness, and a thoroughness before unknown. The proper solution of military problems requires the reaching of a sound decision as to what is to be done."*
>
> Sound Military Decisions
> U.S. Naval War College, 1936

Despite our extraordinary technological advancement, reaching a sound decision to solve a complex, time-critical military problem is as formidable a task today as it was in 1936, even for the most seasoned, imaginative, and intelligent decision maker. Indeed, compelling research spanning the forty-four year interval suggests that holistic, unaided decision making often proves faulty when applied to complex problems involving conflictive objectives, uncertainty, and risk.[1]

Motivated by the strength of that research evidence, by the critical nature of today's national security decisions, by the heavy responsibilities commonly imposed on Defense decision makers, and by the promise of innovative technology to aid and promote accountability in the decision-making process, the Defense Advanced Research Projects Agency (DARPA) recently sponsored a program of basic research and

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[1] The literature is vast. Since 1970 more than one thousand books, articles, and technical reports have been published on the subject. See, for example, Slovic, Paul; Fischhoff, Baruch; and Lichtenstein, Sarah, Behavioral Decision Theory, Technical Report DDI-7 (Eugene, Oregon: Oregon Research Institute, September 1976).

exploratory development to examine decision-making processes and to develop practical decision-aiding methodology for application within the Department of Defense (DoD). Spanning the seven-year period from 1972 to 1979, DARPA's Advanced Decision Technology Program produced incontroversial evidence that underscored the need for practical and useful decision-aiding methodology for Defense decision makers. In response to that need and as an integral part of the program, DARPA sponsored the development of decision-aiding computer software that embodies the fundamental concepts of the management discipline of decision analysis.

Most of the software decision aids are generic model-building aids. That is, in most cases the software was designed to enable a user knowledgeable in decision analysis methodology to build and tailor a model to fit a specific decision problem under consideration. Thus, any one decision aid may be used to create and exercise any number of specific decision-aiding models. The resulting models may be constructed, stored, retrieved, edited, extended, and exercised electronically using computer technology.

The family of decision-aiding software was applied extensively on an exploratory basis to the solution of diverse, important, real-world problems throughout the DoD during the period 1976 to 1979. The pilot applications of the decision aids included, but were not limited to:

a. use by the staff sections of Headquarters, U.S. European Command and its three component service commands--the aids were applied to more than forty specific decision problems and remain in active use at the present time;

b. use by the U.S. Army in the evaluation of alternative single channel ground and airborne radio system (SINCGARS) configurations for the post-1980 time period;

c. use by the Intelligence Center, Pacific in assessing the likelihood of adversary actions;

d. use by the National Security Council in deciding what kinds of computer technology were appropriate for export sale to the Soviet Union;

e. use by the Central Intelligence Agency and DoD/International Security Affairs (ISA) in applying Pareto-optimal negotiation strategies to the Panama Canal treaty negotiations and to the Philippine base-rights treaty negotiations;

f. use by the Department of Transportation in conducting international negotiations on tanker safety;

g. use by Headquarters, U.S. Marine Corps as an organizing vehicle for the preparation of the FY 1979 and FY 1980 Program Objectives Memorandum (POM); and

h. adoption of the methodology by the U.S. Marine Corps as the basis for a standard procedure used to assess the readiness of combat units.

Those and many other diverse pilot applications of the decision aids over the three-year period successfully demonstrated their potential applicability to important Defense decision problems.

The documentation effort described herein supports DARPA's desire to transfer the decision-aiding software to the broadest possible user population. However, since few potential users of the aids have access to the IBM 5100 computer or to the APL computer programming language on which the aids were developed, the documentation is itself generic in nature. That is, it has been written independently of computer and programming language. Thus, a prospective user agency should be able to apply the documents to the development of software that implements an operational version of the aids on any host computer using any computer language.

This manual briefly discusses the need for decision aids, identifies the seven decision aids that were chosen for documentation, and describes the nature of the documents available to prospective users. A complete list of the documents appears in Section 10.0.

2.0 DECISION AIDS

"The responsibility for making a decision is solely that of the commander, and the precise mental processes he uses in its formulation are his own concern. Regardless of the techniques employed, a sound decision will reflect a thorough analysis of all information pertinent to the solution."

FMFM 3-1, Command and Staff Action
U.S. Marine Corps, 1970

2.1 The Need for Decision Aids

More than twenty years ago Herbert Simon, the 1978 Nobel Laureate, wrote that the "capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behavior in the real world--or even for a reasonable approximation to such objective rationality."[1] Rational decision making is even further strained in crisis decision situations, which are normally attended by urgency, risk, conflictive objectives, inconclusive information, and unclear personal judgments. Understandably, complex crisis situations offer all too abundant opportunities for misperception, miscommunication, and misunderstanding. It is rare that a decision choice reflects the implications of a thorough analysis of all the information pertinent to the solution.

[1] Herbert A. Simon, Models of Man: Social and National (New York: Wiley, 1957).

Indeed, one of the major results of decision research over the past decade is that decision makers and their staffs systematically and predictably violate the principles of sound decision making when they attempt to cope with the uncertainty that attends most decision problems. Humans are notoriously biased when judging the likelihood of future events or otherwise performing probabilistic tasks. Furthermore, the research shows that the deficient reasoning that humans apply to probabilistic tasks is present in the problem structuring and value assessment tasks as well. The biased reasoning can be traced to various intuitive and superficial strain-reducing strategies that decision makers commonly employ to analyze information.

The deficiencies of those strategies manifest themselves in several areas of the decision-making process. To illustrate those areas consider Figure 2-1, which is a decision tree model of a relatively simple decision situation. The model depicts a decision problem having two alternative courses of action: D_1 and D_2. The problem is to choose one of those two alternatives. Presumably, the choice is irrevocable; characteristic of most important decisions, once the choice is implemented there is no turning back.

The model shows that if course of action D_1 is selected, then the eventual outcome will be O_1, with certainty. However, should course of action D_2 be selected, then the eventual outcome will be either O_2 or O_3, depending on how the uncertain event unfolds. Presumably the key uncertainty is an event (such as weather or adversary intentions) not under the control of the decision maker.

One area of deficiency is that of coping with the uncertain event. Most decision makers will admit to the

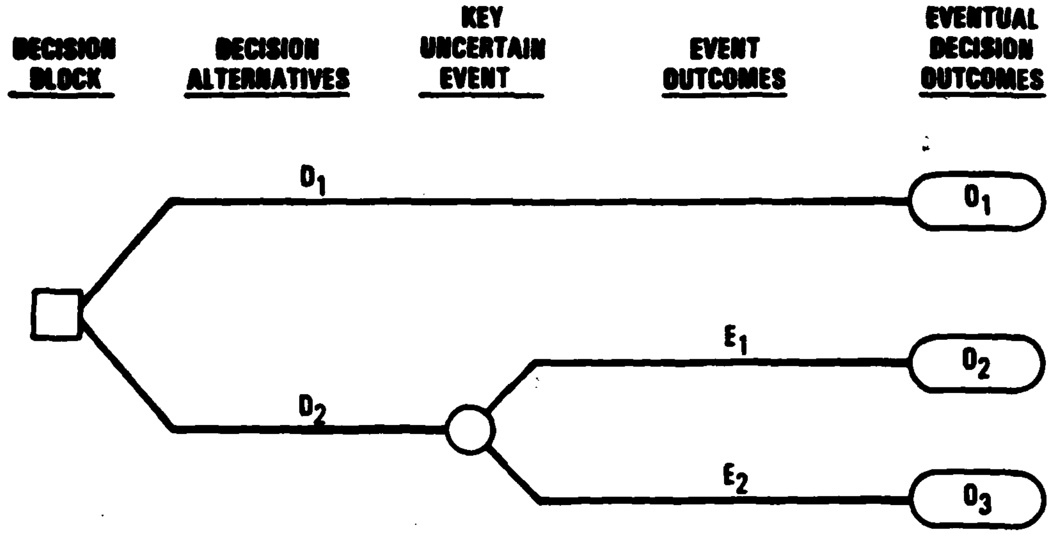

Figure 2-1
A SIMPLE DECISION TREE MODEL

uncertainty they face, but they most often deal with it by attempting to remove the uncertainty altogether through a process of information collection. Instead, they should accept the probabilistic nature of the real-world and deal with the uncertainty in probabilistic terms. That is, referring to Figure 2-1, they should assess the relative likelihoods of the two event outcomes, E_1 and E_2. As evidence becomes available, it should be processed to update those relative likelihoods. Probability theory is the relevant methodological base for assessing and communicating uncertainty.

Another distinct area of deficiency is that of evaluating the relative attractiveness of the three possible outcomes of the decision problem, O_1, O_2, and O_3. Sweeping absolute judgments (possibly entangled with the uncertain event) are often applied to that task. Instead, the decision maker should isolate the analysis of consequences from the analysis of uncertainty, and develop criteria for assessing relative preferences regarding the decision outcomes. Utility theory is the relevant methodological base for assessing and communicating preference.

Another area for concern is that of logically integrating the informed probability assessment of the uncertain event with the informed utility assessment of the decision outcomes to arrive at a final choice: to implement course of action D_1 or D_2. The assessment and integration process is a formidable task, and one that if not done systematically often leads to a decision choice that does not cohere with the organizational value structure.

The decision-aiding software described in this Guide was designed to promote sound decision making through systematic normative procedures that help decision makers overcome the judgmental deficiencies described above.

2.2 Decision Analysis

The software described herein fulfills the role of methodological decision aids. All of the software has its roots in the management discipline of decision analysis, a decision-making strategy that dates from the mid-1960's but whose roots extend into the 18th century concepts of probability and utility. Indeed, probability theory and utility theory together form the foundations of decision analysis.[2]

[2] There is a vast literature on decision analysis. For an introductory treatment the reader should refer to Howard Raiffa, Decision Analysis (Reading, Massachusetts: Addison Wesley, 1968); Dennis V. Lindley, Making Decisions (London: Wiley, 1971); Rex V. Brown, Andrew S. Kahr, and Cameron R. Peterson, Decision Analysis for the Manager (New York: Holt,

Simply put, the discipline assists planners and decision makers in choosing between alternative courses of action by systematically decomposing, quantifying, and examining the implications of the relevant considerations, however subjective and tenuous they may be, that bear on the decision problem. The overall goal of decision analysis is to ensure that the ultimate plan or decision choice is a fully coherent one; that is, a choice that is fully consistent with the organizational goals and objectives, value structure, and informed beliefs. In addition, the inherently quantitative framework imposed by decision analysis serves the planning and decision-making process in several other ways. For example, the approach clarifies and makes explicit the important subjective value structure and rationale underlying the problem. That process, in turn, builds additional insight into the problem, promotes accountability in the decision-making process, and facilitates communication and understanding among all of those involved in the process.

2.3 The Seven Decision Aids

Most of the decision-aiding software is generic model-building software that is applicable to broad classes of decision problems. That is, as opposed to providing fixed, uniquely configured models for specific applications, most of the software permits the user to construct and tailor an individual model to fit the particular problem at hand.

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[2]Rinehart and Winston, 1974); or Scott Barclay, Rex V. Brown, Clinton W. Kelly, Cameron R. Peterson, Lawrence D. Phillips, and Judith Selvidge, Handbook for Decision Analysis, Technical Report TR-77-6-30 (McLean, Virginia: Decisions and Designs, Inc., 1977).

The aids are described briefly below. A more detailed description of each aid appears in the following seven chapters.

1. DECISION (Decision Tree Model) - This generic model-building software aid enables users to construct, specify, and exercise classical decision tree models of the kind shown in Figure 2-1. DECISION processes the specified probabilities of the uncertain events and the assessed utilities of the possible decision outcomes to arrive at a recommended course of action.

   DECISION is described in Section 3.0.

2. OPINT (Operations-Intelligence) - This generic model-building software aid enables users to construct and specify a restricted version of a decision tree model. The model is restricted to one decision block followed by one key uncertainty that attaches to each alternative course of action. OPINT assists the user in specifying the consequences of the decision outcomes. It processes the specified event likelihoods and the assessed values of the decision outcomes to arrive at a recommended course of action.

   OPINT is described in Section 4.0.

3. INFER (Inference) - This generic model-building software aid enables users to construct and specify influence diagram models that represent dependency relationships between uncertain future events. INFER processes direct and conditional probability assessments to produce unconditional

probabilities for any event of interest. INFER supports Bayesian updating of prior probabilities in light of new evidence.

INFER is described in Section 5.0.

4. HIER (Hierarchical Inference) - This generic software aid enables a user to assess the implications of evidence relating to hypotheses of interest concerning a key future event.

   HIER is described in Section 6.0.

5. SCORING RULE - This specialized software aid administers a subjective probability assessment test designed to improve the calibration of probability assessors.

   SCORING RULE is described in Section 7.0.

6. EVAL (Evaluation) - This generic model-building software aid enables users to construct and specify multi-attribute utility models for evaluating various alternative systems, plans, or courses of action under conditions of relative certainty.

   EVAL is described in Section 8.0.

7. RAM (Resource Allocation Model) - This generic model-building software was developed specifically to aid those managers who are responsible for the annual preparation and submission of the Program Objectives Memorandum (POM). RAM permits users to perform cost/benefit comparisons and trade-offs among programs competing for limited funds.

   RAM is described in Section 9.0.

3.0 DECISION

DECISION, the name of the system described in this section, is derived from Decision Tree. The system aids the decision-making process by enabling users to construct, specify, and solve classical decision tree models of problems of choice.

3.1 Purpose

The overall purpose of DECISION is to assist decision makers in building and exercising decision tree models that approximate real-world decision problems. A typical (but incomplete) decision tree structure that could be implemented using DECISION is shown in Figure 3-1. The structure shows, proceeding from left to right, three immediate decision choices, each followed by uncertain future events and/or subsequent decisions that lead eventually to the possible outcomes. The user must specify the relative likelihood (probability) of the uncertain events and the relative desirability (utility) of the possible outcomes.

Consistent with the user's specifications, DECISION will indicate the rational decision choice (the one having the maximum expected utility).

3.2 Intended Users

Decision makers and their operations and/or planning staff. Anyone who must resolve alternative courses of action conditioned by multiple objectives and key uncertainties.

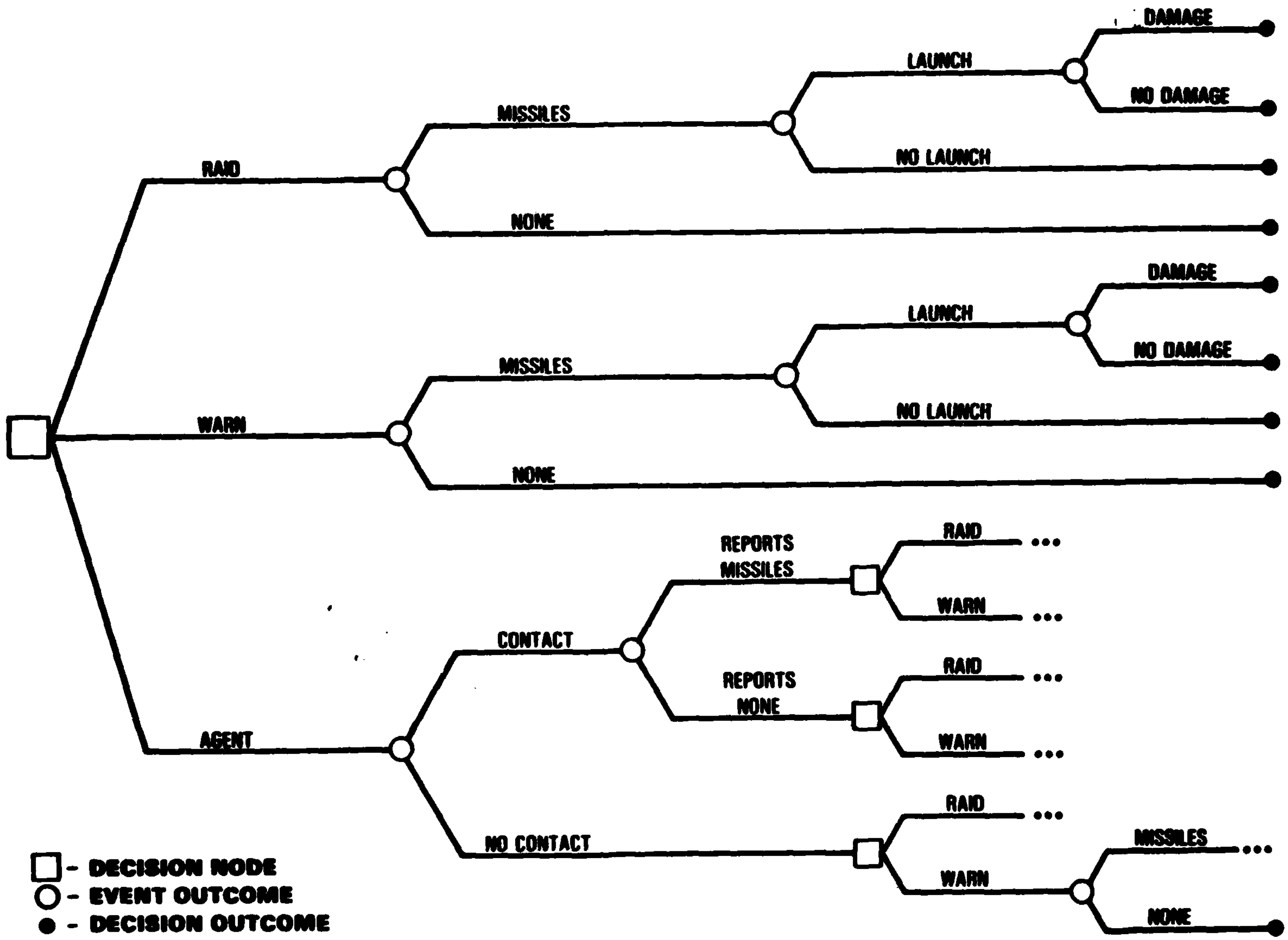


Figure 3-1
A TYPICAL DECISION TREE

3.3 Potential Areas of Application

- Tactical operations
- Crisis decision making
- Contingency planning
- Strategic planning

3.4 Technical Concepts

- Decision tree modeling
- Probability assessment
- Utility assessment
- Multi-attribute decision theory
- Expected value theory

3.5 System Summary

The DECISION software permits decision makers to construct, store, retrieve, and revise decision tree models of the kind shown in Figure 3-1. The user may identify multiple criteria for assessing the relative preferences (utility) regarding the various decision outcomes. In addition, the user must specify the relative importance of the criteria. The user must also specify the probabilities of the uncertain events.

DECISION processes the user specifications to produce the values of the expected utility for all of the branches of the tree. The overall result is the expected utilities associated with the initial decision branches.

3.6 User Inputs

The user must specify (1) the format of the decision tree, (2) the criteria to be used for evaluating the eventual outcome of the problem, (3) the relative importance of the criteria, (4) the relative utility of the possible outcomes of the problem for each ctiterion, and (5) the probability of occurrence of each uncertain event.

3.7 System Outputs

DECISION processes the input data to produce the expected utility associated with each branch of the decision tree. The major result of interest is a display of the utilities associated with the initial decision choices. The rational choice is that course of action having the greatest expected utility.

Figure 3-2 shows a display of the overall results that might obtain from the decision tree shown in Figure 3-1.

1 OVERALL RESULT

CRITERIA:	NAT-S	DOM-A	FOR-A	
CRIT. WEIGHTS:	50	25	25	TOTAL
1) RAID	80	42	51	63
2) WARN	62	74	81	70
3) AGENT	41	60	72	54

Figure 3-2
TYPICAL RESULTS MATRIX

The figure indicates that three criteria (the impact on national security, domestic affairs, and foreign affairs) were used to evaluate the outcomes, and they were weighted 50%, 25%, and 25%, respectively. The matrix also shows the relative satisfaction each course of action provides under each criterion. For example, having chosen the RAID course of action, the decision maker expects 80% satisfaction with respect to national security, 42% satisfaction with respect to domestic affairs, and 51% for foreign affairs, leading to a weighted overall expected utility of 63%. Consistent with the overall results, the rational choice would be to WARN, since that course of action provides the greatest expected utility.

4.0 OPINT

OPINT, the name of the system described in this section, is an abbreviation for Operations and Intelligence, reflecting the system's applicability to operational decision making based on intelligence estimates. OPINT permits the user to implement, under a severe time constraint, a specialized and restricted decision tree model of a real-world crisis situation.

4.1 Purpose

OPINT assists crisis decision makers in rapidly resolving a difficult problem of choice in the face of one key uncertainty and multiple conflictive objectives. Based on user inputs, the system identifies the course of action having the least expected regret.

4.2 Intended Users

Crisis decision makers and their operations staff.

4.3 Potential Areas of Application

- Crisis decision making
- Contingency planning

4.4 Technical Concepts Underlying the Aid

- Decision tree modeling
- Probability assessment
- Utility and regret assessment
- Multi-attribute utility assessment
- Expected value theory

4.5 System Summary

OPINT accommodates a highly restricted decision tree format that accommodates just one decision and one key uncertain event. The uncertain event attaches to each decision alternative. Figure 4-1 shows the typical format of an OPINT decision model. Multiple criteria may be used to specify the relative dissatisfaction (regret) associated with the decision outcomes.

The user must also specify the relative importance weights of the criteria, the relative likelihood (probability) of the uncertain event outcomes, and for each criterion the relative regret associated with each decision outcome.

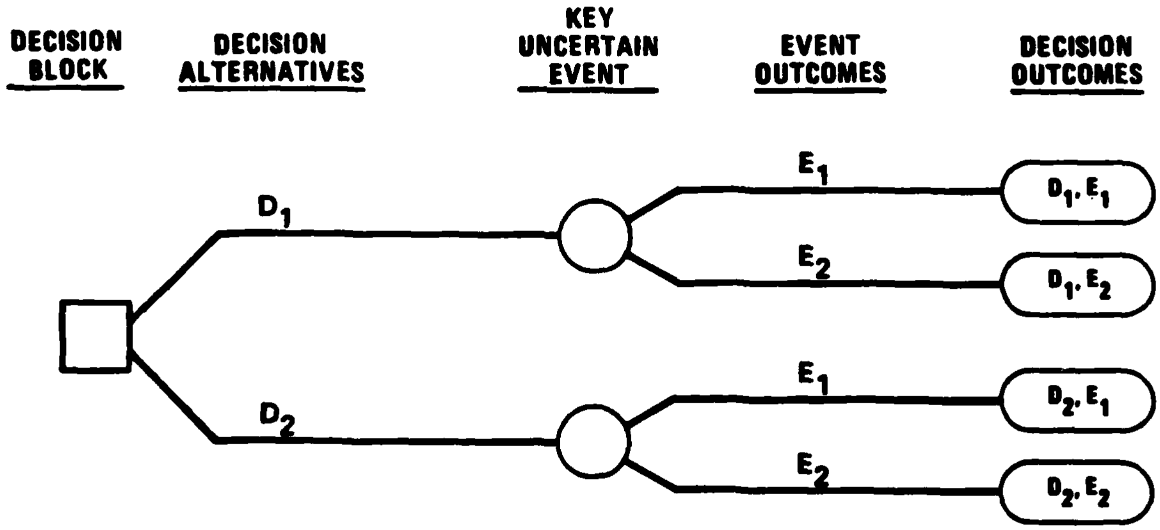


Figure 4-1
AN OPINT MODEL

OPINT processes the input information to produce the expected regret associated with each course of action. It also provides a sensitivity analysis function that displays the optimal choice of decision alternatives as a function of changes in the event outcome probabilities and/or changes in the weights assigned to the criteria.

4.6 User Inputs

The user must specify (1) the courses of action under consideration, (2) the possible outcomes of the key uncertainty and their probabilities of occurrence, (3) the criteria to be used in judging the relative dissatisfaction associated with the decision outcomes, (4) the relative importance of the criteria, and (5) the relative regrets ssociated with the decision outcomes for each criterion.

4.7 System Outputs

OPINT processes the input information to produce the expected regret associated with each course of action. The rational choice is that course of action leading to the least expected regret.

OPINT also produces two kinds of sensitivity analysis. Figure 4-2 shows the sensitivity of the courses of action to changes in an event outcome probability. The matrix displays the expected regret associated with each of the four courses of action (listed vertically) as a function of changes in the probability of the event NONE, varied from 0 to 100% in steps of 10%. For each probability, the least expected regret is identified by an asterisk. Arrows indicate a change in the best course of action due to the change in probability.

EXPECTED VALUE WHEN PROBABILITY OF NONE IS:											
	0	10	20	30	40	50	60	70	80	90	100
NORMAL	-57	-51	-45	-40	-34	-28	-23*	-17*	-11*	- 6*	0*
LOW PROF	-50	-46	-42	-38	-34	-29	-25	-21	-17	-13	-9
MED PROF	-27	-27	-27	-26*	-26*	-25*	-25	-25	-24	-24	-24
EVAC PST	-26*	-26*	-26*	-27	-27	-28	-28	-28	-29	-29	-29
				↑			↑				

Figure 4-2

SENSITIVITY TO PROBABILITY

Figure 4-3 shows the sensitivity of the courses of action to changes in the importance weight of a specified criterion. The format is identical to that of Figure 4-2, except that the criterion importance weight is varied from 0% to 100% in lieu of the event outcome probability.

EXPECTED VALUE WHEN WEIGHT OF EXPOSURE RISK IS:											
	0	10	20	30	40	50	60	70	80	90	100
NORMAL	-22*	-23*	-25*	-26*	-27	-29	-30	-31	-33	-34	-35
LOW PROF	-32	-31	-31	-30	-29	-29	-28	-27	-27	-26	-25
MED PROF	-44	-39	-35	-31	-27*	-23*	-19*	-15*	-11	-7	-3
EVAC PST	-49	-44	-40	-35	-30	-25	-20	-15	-10*	-5	-1*
					↑				↑		

Figure 4-3

SENSITIVITY TO CRITERION WEIGHT

5.0 INFER

INFER, the name of the system described in this section, is an abbreviation for Inference, reflecting the logical process implemented by the software.

5.1 Purpose

The purpose of the INFER system is to assist intelligence analysts and forecasters by providing them a systematic procedure for organizing and analyzing difficult probability assessments by using inference models and influence diagrams.

5.2 Intended Users

Intelligence analysts, planners, and forecasters.

5.3 Potential Areas of Application

- Preparation of intelligence estimates
- Crisis decision making
- Contingency planning

5.4 Technical Concepts Underlying the Aid

- Influence diagrams
- Direct probability assessment
- Conditional probability assessment
- Bayesian inference

5.5 System Summary

INFER aids the probability assessment task by enabling users to create, store, retrieve, exercise, and refine inference models that approximate causal relationships between several uncertain events.

The models captured by INFER are based on a methodological approach known as influence diagramming. Figure 5-1 shows a typical influence diagram. The diagram indicates that the outcome of the event of interest, Event E, is influenced by three preceding events, Events A, B, and C. The diagram also indicates the presence of an indicator, Indicator X, whose future occurrence will modify the likelihoods of the outcomes of Event C and hence Event E.

INFER processes the user-specified influence diagram and associated assessments to produce the unconditional probabilities of the outcomes of all of the conditioned events. The major result is the probabilities of the outcomes of the key event of interest (Event E in Figure 5-1).

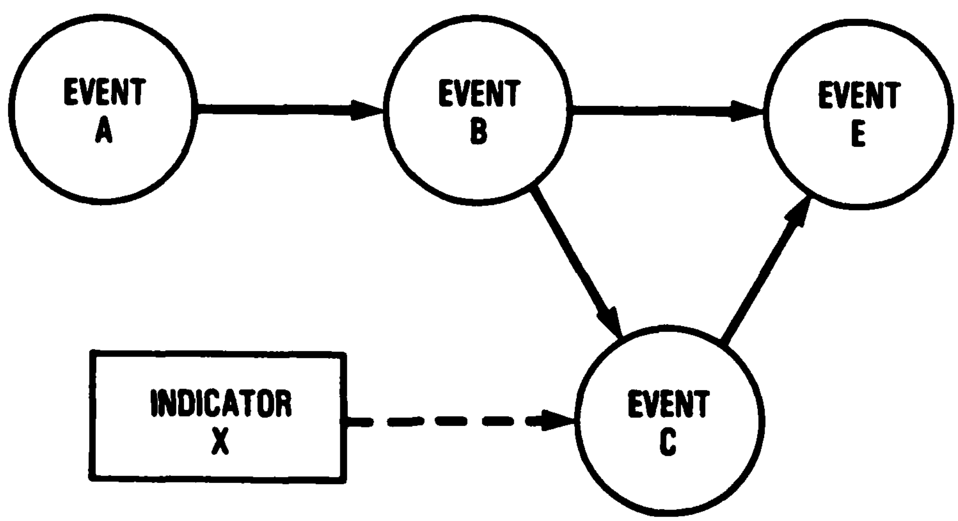


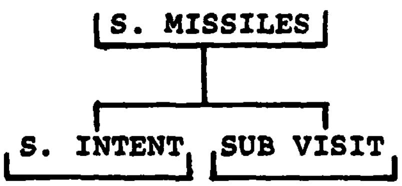
Figure 5-1
AN INFLUENCE DIAGRAM

5.6 User Inputs

The user must specify (1) the format of the influence diagram, (2) the possible outcomes of each event, (3) probabilities of the outcomes of each unconditioned event (Event A in Figure 5-1), (4) conditional probabilities of the outcomes of each conditioned event, and (5) Bayesian likelihood ratios for each indicator.

5.7 System Outputs

INFER processes the user input information to produce the unconditional (marginal) probabilities of the outcomes of each conditioned event. Figure 5-2 shows a typical output display. The diagram in Figure 5-2 indicates that the event of interest, S. MISSILES, is influenced by two other events, S. INTENT and SUB VISIT. The matrix lists vertically the four possible outcomes of the two conditioning events and, in parentheses, their joint probabilities.



		-- S. MISSILES --	
S. INTENT/SUB VISIT		PRESENT	NOT
SUPPORT R./YES	(33)	95	5
SUPPORT R./NO	(8)	1	99
NO SUPPORT/YES	(48)	20	80
NO SUPPORT/NO	(11)	1	99
MARGINAL PROBABILITY		32	68

Figure 5-2
AN OUTPUT DISPLAY

It also shows the user-supplied probabilities for the two outcomes of S. MISSILES (PRESENT and NOT) conditional on the joint influencing event being true. The result of interest is the unconditional (marginal) probabilities. The figure indicates a 32% probability that S. MISSILES are present.

The user may set indicators either ON (observed) or OFF (not observed). If indicators are observed, INFER recomputes the entire chain of posterior probabilities based on the prior probabilities and the Bayesian likelihood ratios supplied by the user.

6.0 HIER

HIER, the name of the system described in this section, is an abbreviation for Hierarchical Inference, reflecting the logical process implemented by the software.

6.1 Purpose

The purpose of the HIER system is to assist intelligence analysts and forecasters by providing them with a systematic procedure for organizing and analyzing probability assessments by using hierarchical inference models.

6.2 Intended Users

Intelligence analysts, planners, and forecasters.

6.3 Potential Areas of Application

- Preparation of intelligence estimates
- Crisis decision making
- Contingency planning

6.4 Technical Concepts Underlying the Aid

- Hierarchical inference
- Conditional probability assessment
- Bayesian inference

6.5 System Summary

HIER aids the probability assessment task by enabling users to construct and exercise hierarchical inference models that approximate complex causal relationships concerning specific hypotheses about an uncertain event. HIER links the hypotheses with various activities, indicators, and supporting data whose occurrence or lack of occurrence would influence the likelihood of each hypothesis.

Figure 6-1 shows an illustrative hierarchical structure. The figure indicates that the relative likelihood of certain hypotheses (H) would be directly influenced by certain data (D^1 and D^3) and the presence of certain activities (A^2, A^4, and A^5). Similarly, the activities are influenced by a complex structure of indicators (I) and data (D). Note that the input (bottom-level) nodes are all data nodes.

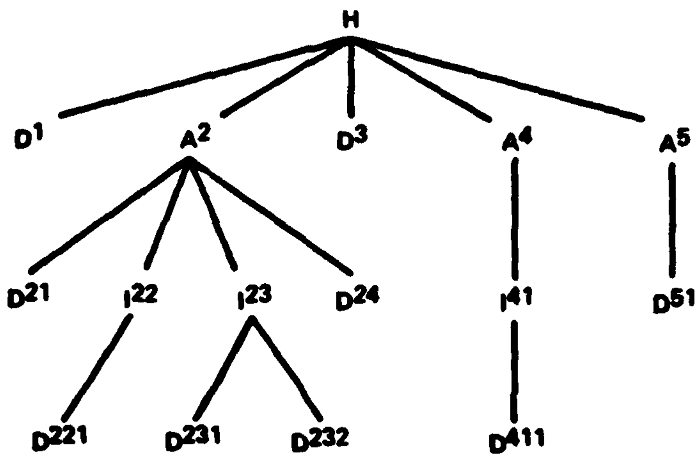


Figure 6-1
ILLUSTRATIVE HIERARCHICAL STRUCTURE

HIER enables the user to construct the complete hierarchical structure and specify the various conditional probabilities and direct assessments that link the lower-level data nodes of the structure with the higher-level nodes. HIER processes the user specifications to produce the updated relative probability for each hypothesis about the event of interest.

6.6 User Inputs

The user must specify (1) the complete format of the hierarchical structure, (2) prior probabilities for each hypothesis about the future event, (3) probability matrices for the conditioning activities and indicators, and (4) direct assessments for the data nodes. Figure 6-2 shows a representative hierarchical structure for a hypothetical assessment problem. Note the linkage of hypotheses, supporting activities, key indicators, and specific data. The figure does not indicate the breakdown of the nodes into their components nor does it show the specified probability assessments.

6.7 System Outputs

HIER processes the user input specifications to produce the posterior probabilities of the hypotheses about the uncertain event. Figure 6-3 shows the format of a typical overall result.

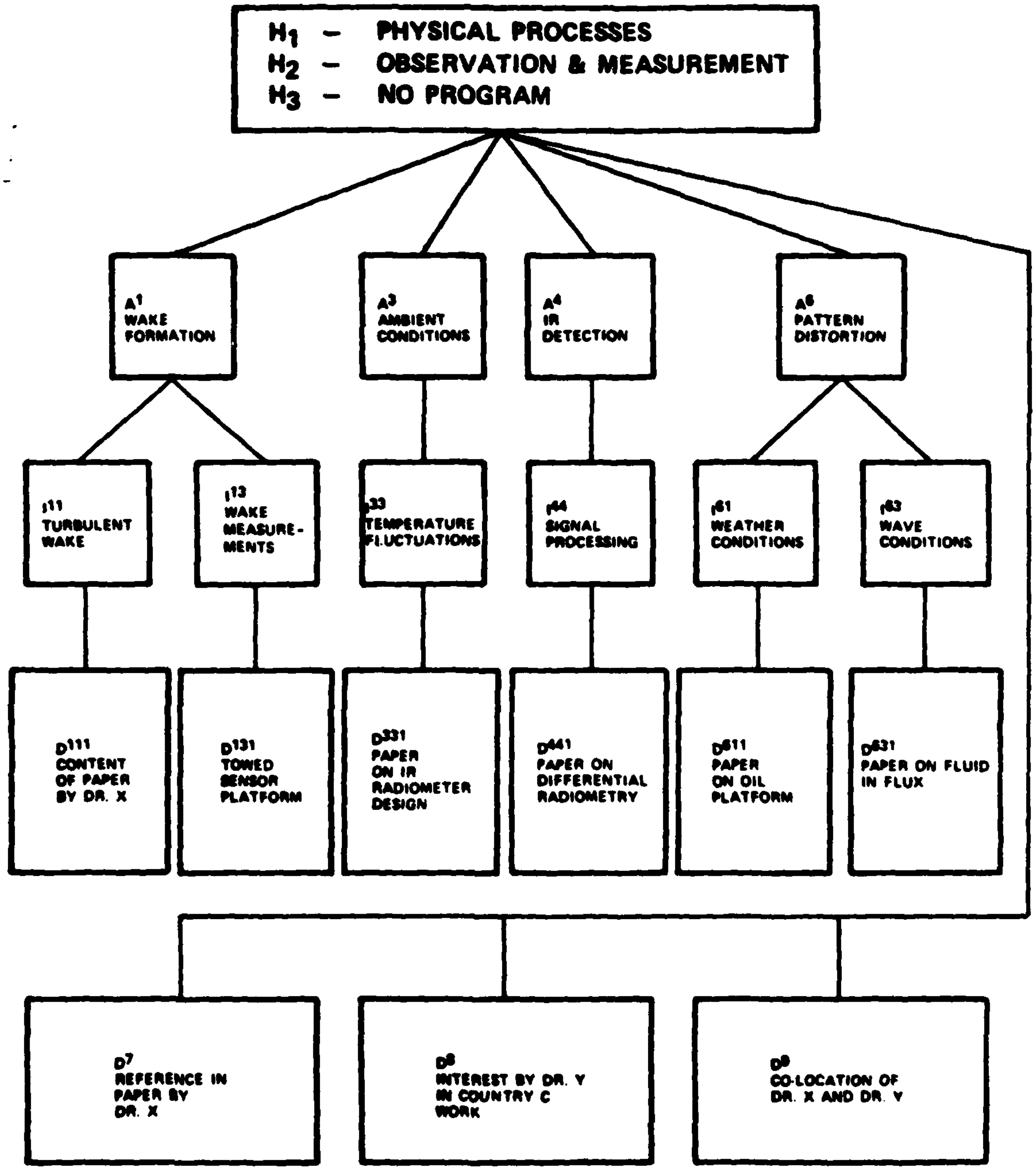


Figure 6-2

HYPOTHETICAL HIERARCHICAL STRUCTURE FOR SUBMARINE DETECTION PROGRAM, COUNTRY B

CURRENT PROBABILITY ASSESSMENTS:

	HYPOTHESES	PRIORS	LIKELIHOODS	POSTERIORS
1.	Active Cooperation	25.00	5.00	6.25
2.	Reduced Tensions	20.00	80.00	80.00
3.	Political Hostility	20.00	5.00	5.00
4.	Active Provocation	30.00	5.00	7.50
5.	Aggression	5.00	5.00	1.25

Figure 6-3

SAMPLE RESULT

7.0 SCORING RULE

SCORING RULE, the name of the system described in this section, is a short description of the function performed by the software, reflecting the system's procedure for testing, scoring, and training probability assessors.

7.1 Purpose

The overall purpose of the SCORING RULE system is to reduce the calibration bias of individual probability assessors and thereby improve the accuracy of probability assessments. That, in turn, will improve the accuracy of intelligence estimates and the quality of the decisions based on those estimates.

7.2 Intended Users

Intelligence analysts, planners, forecasters; anyone who must analyze, assess, and communicate the likelihood of future events.

7.3 Potential Area of Application

- Training intelligence analysts, planners, and forecasters

7.4 Technical Concepts Underlying the Aid

- Subjective probability
- Calibration of probability assessments
- Proper scoring rules

7.5 System Summary

The SCORING RULE system administers an interactive subjective probability assessment test (SPAT) to the user. SPAT consists of a series of short questions, each of which is accompanied by two answers, only one of which is correct. A typical question appears in Figure 7-1.

OF THE 48 CONTIGUOUS STATES, THE NORTHERNMOST IS:

1. MAINE
2. MINNESOTA

Figure 7-1
A TYPICAL SPAT QUESTION

The user must respond to each question by identifying the correct answer and specifying the probability (degree of confidence) that the cited answer is correct. The system processes the user responses and displays the results in the form of a calibration diagram, as shown in Figure 7-2. The diagram indicates how well the user's assessments corresponded with the actual hit rate (the percentage of questions answered correctly). Ideally, they would correspond perfectly. For example, a perfectly calibrated analyst would be correct in 70% of all estimates that were assessed as 70% likely.

7.6 System Inputs

The input to the SCORING RULE system consists of responses to the SPAT questions. For example, a typical response to the question asked in Figure 7-1 might be: 1 .8, implying that the user is 80% confident that Maine

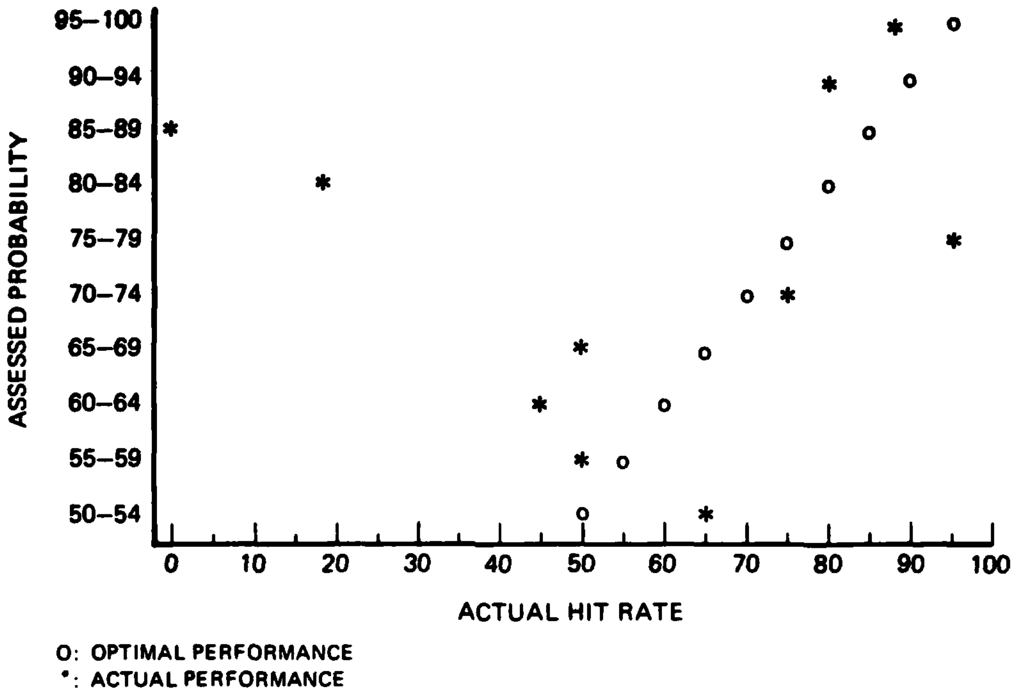


Figure 7-2
CALIBRATION DIAGRAM

extends farther north than Minnesota. Typically, one hundred questions and responses comprise a SPAT session. The questions may be general in nature or related to a specialized body of knowledge.

7.7 System Outputs

At the user's option, SCORING RULE provides question-by-question feedback that indicates whether the user's answer is right or wrong. The system incorporates a scoring procedure, known theoretically as a proper scoring rule, that is designed to reduce guessing by assigning a win/lose point score consistent with the user's expressed degree of certainty. Accordingly, for each question SCORING RULE also displays the number of points won or lost. Thus, the system's response to the user's answer 1 .8 to the question shown in Figure 7-1 would be: WRONG. YOU LOSE 49 POINTS.

At the conclusion of the test session, SCORING RULE displays the resultant calibration diagram, as shown in Figure 7-2, and an overall user performance measure, expressed as a percentage of the maximum obtainable calibration score.

8.0 EVAL

EVAL, the name of the system described in this section, is an abbreviation for Evaluation, reflecting the system's major area of applicability.

8.1 Purpose

The overall purpose of EVAL is to assist decision makers in solving problems of evaluation, that is, in discriminating among the various alternative systems or other entities or courses of action under consideration. The EVAL approach assumes that the decision maker is fully informed about the alternatives being evaluated; EVAL does not treat uncertainty explicitly.

EVAL ensures that the final evaluation results are totally consistent with the decision maker's expressed goals and value structure. Its use also promotes accountability in the evaluation process by providing an audit trail that links the final results with the input information.

8.2 Intended Users

Decision makers, planners, analysts, operations personnel, source selection staffs; anyone who must perform an important evaluation and selection task.

8.3 Potential Areas of Application

Procurement, source selection, personnel selection, comparative systems analysis, planning, any type of formal evaluation process.

8.4 Technical Concepts Underlying the Aid

- Utility assessment
- Multi-attribute utility theory
- Sensitivity analysis

8.5 System Summary

The fundamental product of EVAL is a user-specified, computer-stored evaluation model. The model accommodates multiple evaluation criteria structured in hierarchical fashion, as shown in Figure 8-1.

The user must specify the hierarchical format, the criteria and their relative importance weights, and values of utility for each of the entities under evaluation. Consistent with those specifications, EVAL displays the aggregate utilities with respect to any desired criterion. The overall result of the evaluation is a display of comparative utilities at the top-most node of the hierarchy. The system also permits the user to perform sensitivity analyses.

8.6 User Inputs

The user must specify (1) the structural format of the model, (2) the names of the criteria, (3) criterion importance weights, and (4) values of the utility of each entity under evaluation for each bottom-level criterion (those circled in Figure 8-1).

8.7 System Outputs

EVAL processes the user inputs to produce comparative utilities with respect to any specified criterion in the

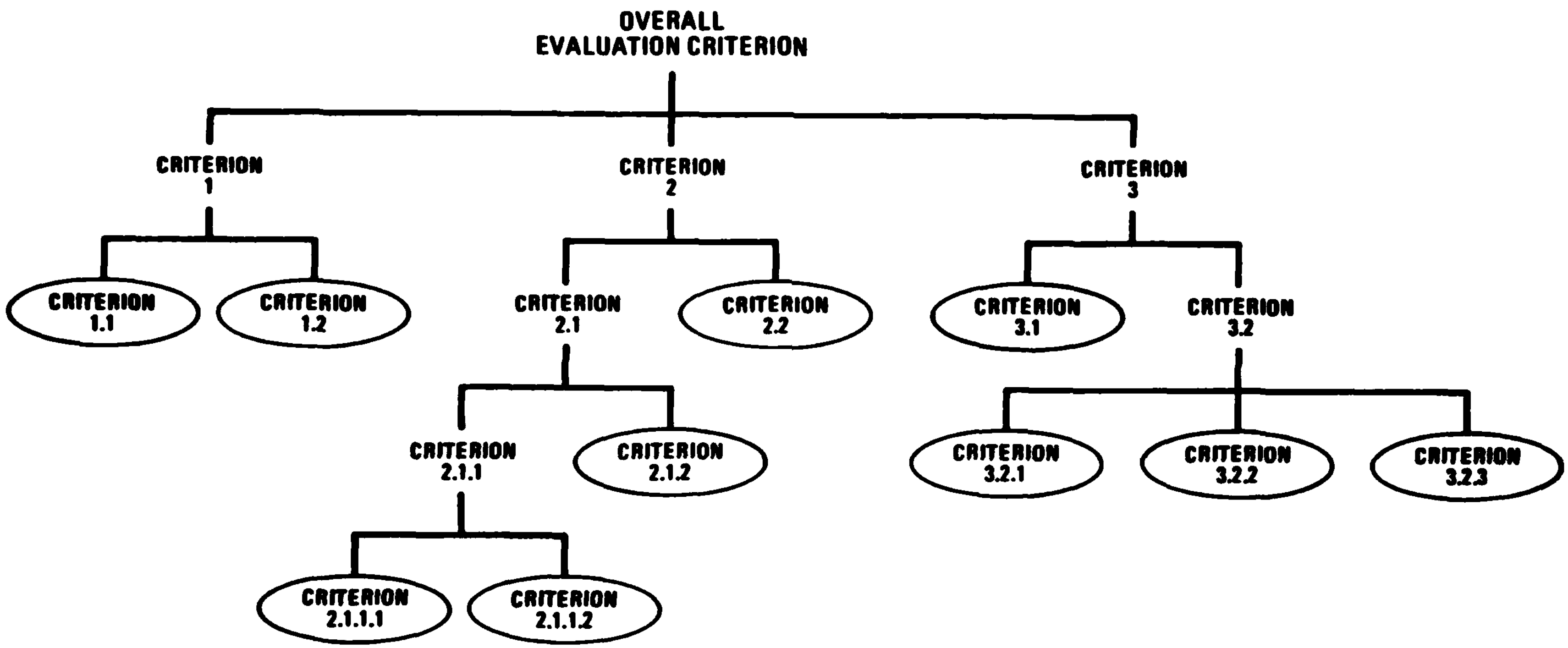


Figure 8-1

FORMAT OF A TYPICAL EVALUATION MODEL

model. Figure 8-2 shows a typical output display for a site selection evaluation. The figure shows that three criteria comprised the overall evaluation result: support of mission, support of relocation, and political considerations. The numbers in parentheses indicate the relative importance weights of the criteria. The matrix shows the aggregate utility of each of the five sites being evaluated with respect to the three criteria. The result of interest is the total utility of each site, which is shown in the last row. Consistent with the input information, the user should select Site D, which provides 73% of complete satisfaction across all of the relevant criteria.

0. OVERALL RESULTS

			SITE A	SITE B	SITE C	SITE D	SITE E
1.	SUPPORT OF MISSION	(52)	61	72	45	80	75
2.	SUPPORT OF RELOCATION	(33)	20	62	70	61	38
3.	POLITICAL CONSIDERATIONS	(15)	81	43	52	76	65
	TOTAL		50	64	54	73	61

Figure 8-2
A DISPLAY OF OVERALL RESULTS

EVAL permits the user to vary the cumulative importance weight of any criterion over a specified range. Figure 8-3 shows a sample sensitivity analysis in which the weight of particular criterion of interest was varied from 0 to 50%. The figure indicates the resultant overall utilities of the sites under evaluation for each specified weight. An asterisk identifies the site having the greatest utility.

Criterion 1.3.3.1.1

SUPPORT OF MISSION--EXISTING SPACE--AVAILABLE STORAGE--COVERED--QUALITY

Current CUMWT: 15

WEIGHT	SITE A	SITE B	SITE C	SITE D	SITE E
0	52	61	57	*76	58
5	51	63	56	*75	59
10	50	64	55	*75	60
15	50	64	54	*73	61
20	49	66	53	*72	62
25	48	67	52	*70	63
30	48	69	51	*70	65
35	47	*71	50	68	66
40	45	*72	50	67	66
45	45	*74	49	65	67
50	44	*75	48	64	68

Figure 8-3

SAMPLE SENSITIVITY ANALYSIS

9.0 RAM

RAM, the name of the system described in this section, is an acronym for Resource Allocation Model, reflecting the system's major area of applicability.

9.1 Purpose

RAM assists decision makers by prioritizing the order of allocating scarce resources to acquire competing systems and/or services. Specifically, RAM was designed to assist those responsible for integrating, preparing, and submitting the annual Program Objectives Memorandum (POM) within the Department of Defense.

9.2 Intended Users

Those responsible for POM preparation and submission, financial officers, and others who must allocate scarce monetary resources.

9.3 Potential Areas of Application

- POM preparation
- Resource allocation

9.4 Technical Concepts Underlying the Aid

- Utility assessment
- Cost-benefit analysis

9.5 System Summary

RAM processes cost and benefit information supplied by the user to produce several different kinds of analyses and reports listing the prioritized order of acquisitions and other relevant information. RAM permits the user to build, store, retrieve, revise, and exercise different resource allocation models and to display and print a variety of different reports for each model.

9.6 System Inputs

RAM requires that the user specify (1) the functional groupings (such as logistics, aviation, etc.) of the candidate acquisition packages, (2) the packages belonging to each functional grouping, (3) the values of benefit and cost for each package within the functional grouping, and (4) a relative importance weight for each functional grouping.

9.7 System Outputs

RAM processes the input information to produce various consolidated reports. For example, Figure 9-1 shows a prioritized list of acquisitions, ordered by increasing cost-benefit ratio. Note, however, that the first item on the list had been declared a "must buy" item by the user; therefore, its cost-benefit ratio was not considered in the prioritization scheme. The numbers to the left of each item name represent the functional area and item number, respectively.

Figure 9-2 shows the costs and the cumulative costs of the items for the five fiscal years from 1980 through 1984.

Other report formats are available to the user.

	ITEM	OVERALL RAM SPONSOR BENEFIT	OVERALL BENEFIT	COST	C/B	RANK
3	2)FACULTY RAISES	30.0	18.0	1017.0	56.6	1
4	3)CAREER PLACEMENT CTR	100.0	35.0	44.0	1.3	2
1	2)ALUMNI SURVEY	25.0	2.5	5.0	2.0	3
2	4)MAINT & RENOVATION	100.0	100.0	250.0	2.5	4
3	1)INTERVIEW & HIRING	55.0	33.0	100.0	3.0	5
4	5)EXTRACURRICULAR	20.0	7.0	29.0	4.1	6
2	1)LAB FACILITIES	60.0	60.0	270.0	4.5	7
5	2)FEDERAL RELATIONS	90.0	18.0	89.0	4.9	8
4	1)STUDENT CENTER	30.0	10.5	52.0	5.0	9
5	1)ALUMNI ASSOCIATION	25.0	5.0	26.0	5.2	10
4	4)HOUSING GUIDE	15.0	5.25	31.0	5.9	11
2	5)INVESTMENT AID	12.0	12.0	72.0	6.0	12
5	3)FOUNDATION SUPPORT	100.0	20.0	132.0	6.6	13
4	2)COUNSELING PROGRAM	45.0	15.75	110.0	7.0	14
3	6)BOOKS & PERIODICALS	100.0	60.0	425.0	7.1	15
5	5)RECRUITING	70.0	14.0	103.0	7.4	16
1	3)ARCHITECTURAL SURVEY	100.0	10.0	80.0	8.0	17
2	3)IN-HOUSE COMPUTER	70.0	70.0	660.0	9.4	18
4	6)HEALTH SERVICES	75.0	26.25	278.0	10.6	19
3	5)FACULTY OFFICE BLDG	80.0	48.0	810.0	16.9	20
1	4)EXPANSION PLANNING	65.0	6.5	113.0	17.4	21
5	4)COMMUNITY INVOLVEMENT	50.0	10.0	244.0	24.4	22
3	4)BUSINESS PROGRAM	70.0	42.0	1200.0	28.6	23
1	1)SECRETARIAL SERVICES	10.0	1.0	95.0	95.0	24
3	3)NURSING PROGRAM	25.0	15.0	1870.0	124.7	25
2	2)ATHLETIC COMPLEX	5.0	5.0	5060.0	1012.0	26

PLEASE RETURN CARRIAGE TO CONTINUE.

Figure 9-1

OVERALL DISPLAY OF ITEMS RANKED IN ASCENDING ORDER

		OVERALL COSTS						CUMULATIVE COST					
	ITEM	FY80	FY81	FY82	FY83	FY84	OTHER	FY80	FY81	FY82	FY83	FY84	OTHER
3	2)FACULTY RAISES	180.0	190.0	202.0	215.0	230.0	0	180.0	190.0	202.0	215.0	230.0	0
4	3)CAREER PLACEMNT CTR	5.0	8.0	9.0	10.0	12.0	0	185.0	198.0	211.0	225.0	242.0	0
1	2)ALUMNI SURVEY	5.0	.0	.0	.0	.0	0	190.0	198.0	211.0	225.0	242.0	0
2	4)MAINT & RENOVATION	40.0	45.0	50.0	55.0	60.0	0	230.0	243.0	261.0	280.0	302.0	0
3	1)INTERVIEW & HIRING	15.0	19.0	21.0	23.0	22.0	0	245.0	262.0	282.0	303.0	324.0	0
4	5)EXTRACURRICULAR	3.0	6.0	6.0	7.0	7.0	0	248.0	268.0	288.0	310.0	331.0	0
2	1)LAB FACILITIES	50.0	50.0	50.0	60.0	60.0	0	298.0	318.0	338.0	370.0	391.0	0
5	2)FEDERAL RELATIONS	15.0	16.0	18.0	19.0	21.0	0	313.0	334.0	356.0	389.0	412.0	0
4	1)STUDENT CENTER	11.0	14.0	10.0	9.0	8.0	0	324.0	348.0	366.0	398.0	420.0	0
5	1)ALUMNI ASSOCIATION	4.0	5.0	5.0	6.0	6.0	0	328.0	353.0	371.0	404.0	426.0	0
4	4)HOUSING GUIDE	18.0	3.0	3.0	3.0	4.0	0	346.0	356.0	374.0	407.0	430.0	0
2	5)INVESTMENT AID	10.0	12.0	14.0	16.0	20.0	0	356.0	368.0	388.0	423.0	450.0	0
5	3)FOUNDATION SUPPORT	23.0	25.0	26.0	28.0	30.0	0	379.0	393.0	414.0	451.0	480.0	0
4	2)COUNSELING PROGRAM	19.0	20.0	22.0	24.0	25.0	0	398.0	413.0	436.0	475.0	505.0	0
3	6)BOOKS & PERIODICALS	75.0	80.0	85.0	90.0	95.0	0	473.0	493.0	521.0	565.0	600.0	0
5	5)RECRUITING	18.0	19.0	21.0	22.0	23.0	0	491.0	512.0	542.0	587.0	623.0	0
1	3)ARCHITECTURAL SURVEY	14.0	15.0	16.0	17.0	18.0	0	505.0	527.0	558.0	604.0	641.0	0
2	3)IN-HOUSE COMPUTER	280.0	300.0	25.0	27.0	28.0	0	785.0	827.0	583.0	631.0	669.0	0
4	6)HEALTH SERVICES	45.0	51.0	54.0	61.0	67.0	0	830.0	878.0	637.0	692.0	736.0	0
3	5)FACULTY OFFICE BLDG	10.0	300.0	450.0	25.0	25.0	0	840.0	1178.0	1087.0	717.0	761.0	0
1	4)EXPANSION PLANNING	20.0	21.0	23.0	24.0	25.0	0	860.0	1199.0	1110.0	741.0	786.0	0
5	4)COMMUNITY INVOLVEMENT	45.0	47.0	48.0	49.0	55.0	0	905.0	1246.0	1158.0	790.0	841.0	0
3	4)BUSINESS PROGRAM	200.0	210.0	230.0	260.0	300.0	0	1105.0	1456.0	1388.0	1050.0	1141.0	0
1	1)SECRETARIAL SERVICES	15.0	17.0	19.0	21.0	23.0	0	1120.0	1473.0	1407.0	1071.0	1164.0	0
3	3)NURSING PROGRAM	310.0	340.0	370.0	400.0	450.0	0	1430.0	1813.0	1777.0	1471.0	1614.0	0
2	2)ATHLETIC COMPLEX	1000.0	4000.0	20.0	20.0	20.0	0	2430.0	5813.0	1797.0	1491.0	1634.0	0

Figure 9-2

COST OF THE ITEMS

10.0 THE DOCUMENTATION

10.1 Background

The seven decision aids described herein were designed and developed as research products rather than as production software. Because of their research nature, all of the aids were programmed in the APL computer programming language, which was ideally suited to the developmental task. For the same reason, the software was programmed to run on an IBM 5100 portable computer. In that particular software and hardware configuration, the decision aids were tested and applied on a pilot basis in many different Department of Defense (DoD) decision-making contexts and locales over a four-year period. Many of those applications were conducted by military and civilian DoD personnel who had received specialized classroom and on-the-job training on the theoretical background and practical use of the software. In other applications skilled contractor decision analysts used the aids to assist in the analysis and presentation of substantive information provided by DoD experts. In all instances, the choice of the APL language and the IBM 5100 computer proved extremely satisfactory to the task of developing and experimentally applying the decision aids to real-world decision problems.

However, neither the software nor the hardware is suitable for the widespread dissemination and adoption of the decision aids by prospective DoD users. The reasons for that are twofold: first, because APL is not an approved standard language for the production of DoD automated systems (nor is APL found in the repertoire of most DoD programmers) and, second, because the IBM 5100 computer is not in general use within the DoD automated data processing community. Furthermore, it would prove impractical if not impossible to cite a unique software and hardware configuration upon which to base a documentation effort that would satisfy all of the prospective users of the aids.

Accordingly, to ensure its most widespread applicability, the documentation described herein is fundamentally generic in nature. That is, all of the documents, with only one exception (the HIER System Specification), are written without reference to any specific programming language or computer configuration. The documents have been designed to enable responsible personnel at prospective user activities to produce the language-specific computer programs and hardware-specific documentation necessary to implement the decision aids on their own particular computer facilities. The generic documents described herein should greatly ease the prospective user's task of preparing the system-specific documents necessary to implement the aids.

10.2 Types of Documents

In accordance with accepted DoD standards, a complete software documentation effort should address five different audiences: (1) the user of the software system; (2) the functional manager of the system; (3) the computer systems analyst; (4) the computer programmer; and (5) the computer operator. Each audience has different needs and requires a specialized document designed to support those needs.

Consider the audience at a hypothetical activity that intends to implement one of the aids. First, there is the user--that person who wants to use the aid in a real-world context. An intelligence analyst, for example, may want to use the INFER aid. The user requires a Users Manual that explains the aid and describes how to interface with the computer to use the aid. The Users Manual is written in nontechnical language relative to computer science, although it may use technical language relative to the application of the aid.

Second, there is the functional manager of the software system--that person who is responsible for the implementation and performance of the aid. For the INFER aid, for example, the functional manager may be the Director of the Intelligence Staff. The functional manager originates, maintains, and distributes the Users Manual as well as a Functional Description document that lists and describes, in nontechnical language relative to computer science, the specific functions that the aid must perform. The Functional Description explains to computer systems development personnel what the system must do.

The third audience, the technical computer systems analyst, uses the Functional Description to design the logic of the software system and produce a formal System Specification that serves as the basis of the software production task. Thus, the System Specification is a technical document relative to computer science, and is normally based on a specific software and hardware configuration. The computer systems analyst also assists the functional manager in preparing the computer interface portion of the Users Manual.

Fourth, there is the computer programmer, who uses the System Specification to prepare a Program Specification document and language-specific program code. The programmer also prepares a Program Maintenance Manual, which is consulted by the fifth audience, the technical personnel who operate and maintain the computer facility.

Figure 10-1 illustrates the five levels of audience interaction with a software system and the necessary supporting documents: the Users Manual, Functional Description, System Specification, Program Specification, and Program Maintenance Manual.[1]

10.3 Scope of the Documentation Effort

To satisfy their intended audiences, some of the documents shown in Figure 10-1 are computer software- and hardware-specific and others are not. For example, the Program Specification and Program Maintenance Manual are completely software- and hardware-specific. They could not be included in this generic documentation effort. On the other hand, the Functional Description does not reference computer software or hardware--it need only address the functions that the decision aid must perform; it is generic by its very nature.

The Users Manual and the System Specification ordinarily reference the hardware configuration. The user, for example, must be told how to interface with the computer. Nevertheless, both documents can be written independently of language and computer.

Accordingly, to preserve its generic flavor, the scope of the documentation of the decision-aiding software has been restricted to three documents for each aid. The documents comprise a Users Manual, a Functional Description, and a System Specification.

[1] The five documents are necessary but not necessarily sufficient to completely document a software system.

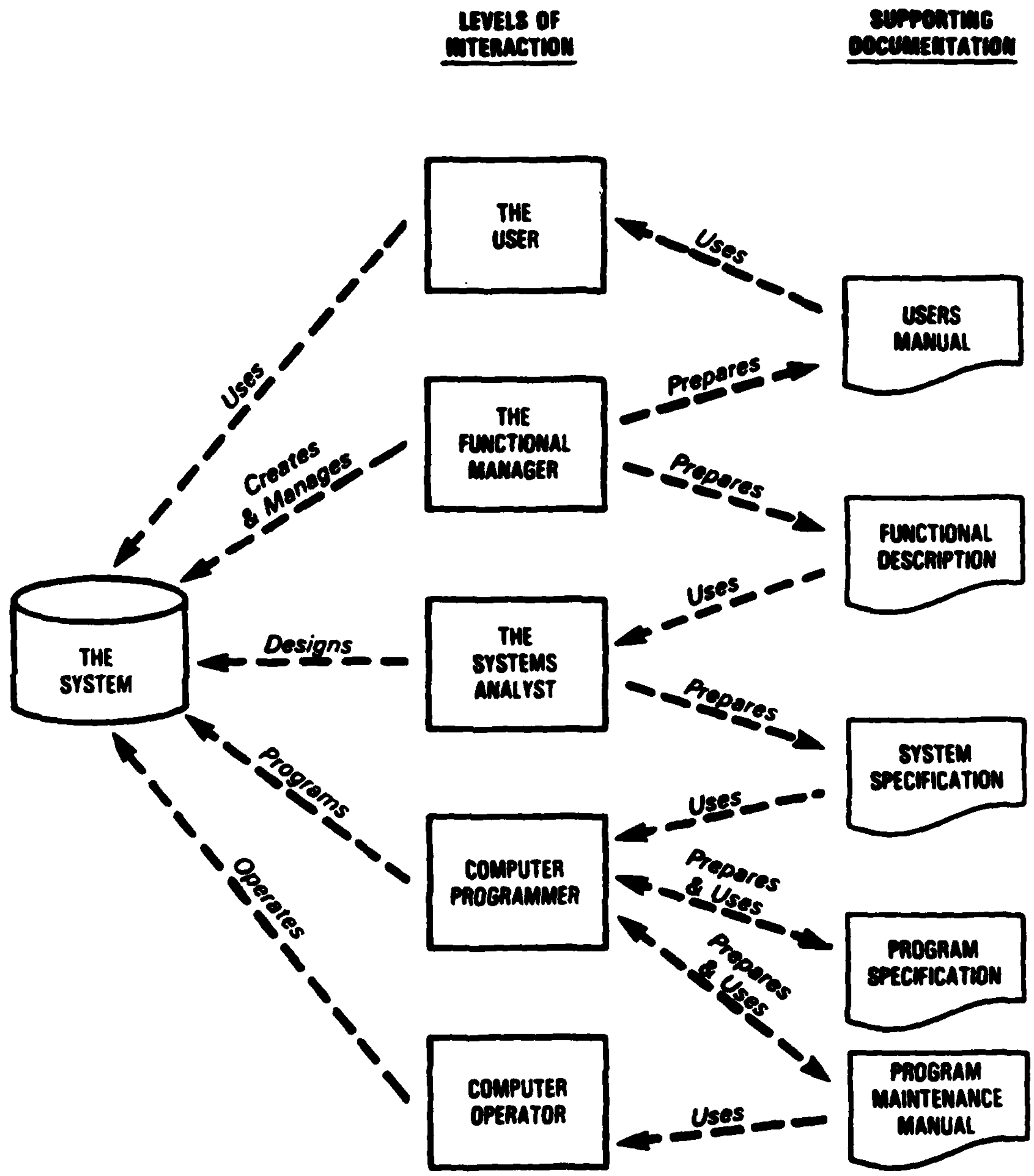


Figure 10-1

LEVELS OF
DOCUMENTATION AND USERS OF DOCUMENTATION

The three documents are intended to guide and facilitate the preparation of language-specific and hardware-specific program code and documentation by a using activity. All three documents are necessary to support a follow-on software development task at a using activity. The purpose of each document is described below.

10.3.1 The Users Manual - The purpose of the Users Manual is to provide users of the decision aid with the background material and the detailed instructions necessary to interface with the aid and interpret the various functions that the aid provides. The manual presents the decision-analytic concepts inherent in the aid, including assumptions and restrictions concerning the use of the aid. Most of the manuals include descriptive case studies.

10.3.2 The Functional Description - The Functional Description provides a delineation of the specific functions that the software must perform. It serves as a formal basis for understanding between the functional manager of the aid and the software development personnel. Together with the System Specification, it serves as the basic reference documentation for the software development and implementation task.

10.3.3 The System Specification - The System Specification is a technical document written exclusively for software development personnel. Together with the Functional Description, it guides the software development effort by identifying the functional requirements of the software system and by providing structured logic diagrams that depict the flow, control, and processing of information within the system. For six of the aids, the System Specification uses a standard hierarchical diagramming technique to depict the structural design and the logical flow of the system. For the seventh (the HIER aid) the System Specification consists of APL programming code.

10.4 List of Documents

The following is a list of the twenty-one manuals that document the seven aids.

10.4.1 The DECISION aid -

- Allardyce, Linda B.; Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: DECISION Users Manual. McLean, Virginia: Decisions and Designs, Inc., November 1979.

- Allardyce, Linda B.; Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: DECISION Functional Description. McLean, Virginia: Decisions and Designs, Inc., November 1979.

- Allardyce, Linda B.; Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: DECISION System Specification. McLean, Virginia: Decisions and Designs, Inc., November 1979.

10.4.2 The OPINT aid -

- Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: OPINT Users Manual. McLean, Virginia: Decisions and Designs, Inc., April 1979.

o Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: OPINT Functional Description. McLean, Virginia: Decisions and Designs, Inc., April 1979.

o Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: OPINT System Specification. McLean, Virginia: Decisions and Designs, Inc., April 1979.

10.4.3 The INFER aid -

o Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: INFER Users Manual. McLean, Virginia: Decisions and Designs, Inc., June 1979.

o Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: INFER Functional Description. McLean, Virginia: Decisions and Designs, Inc., June 1979.

o Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: INFER System Specification. McLean, Virginia: Decisions and Designs, Inc., June 1979.

10.4.4 <u>The HIER aid</u> -

- Amey, Dorothy M.; Gulick, Roy M.; and Kelly, Clinton W. <u>Documentation of Decision-Aiding Software: HIER Users Manual</u>. McLean, Virginia: Decisions and Designs, Inc., in press.

- Amey, Dorothy M.; Gulick, Roy M.; and Kelly, Clinton W. <u>Documentation of Decision-Aiding Software: HIER Functional Description</u>. McLean, Virginia: Decisions and Designs, Inc., in press.

- Amey, Dorothy M.; Gulick, Roy M.; and Kelly, Clinton W. <u>Documentation of Decision-Aiding Software: HIER System Specification</u>. McLean, Virginia: Decisions and Designs, Inc., in press.

10.4.5 <u>The SCORING RULE aid</u> -

- Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. <u>Documentation of Decision-Aiding Software: SCORING RULE Users Manual</u>. McLean, Virginia: Decisions and Designs, Inc., July 1979.

- Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. <u>Documentation of Decision-Aiding Software: SCORING RULE Functional Description</u>. McLean, Virginia: Decisions and Designs, Inc., July 1979.

- Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: SCORING RULE System Specification. McLean, Virginia: Decisions and Designs, Inc., July 1979.

10.4.6 The EVAL aid -

- Allardyce, Linda B.; Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: EVAL Users Manual. McLean, Virginia: Decisions and Designs, Inc., November 1979.

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